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ABSTRACT

This paper gives a brief history of measurement systems and of the controversy surrounding the adoption of the metric system as the standard system in the United States. The metric study called for by legislation in 1968 is described, and recommendations for a coordinated national program to change to the metric system are outlined. Some implications for education are discussed, with brief comments on curriculum, textbooks, teacher training, educational materials, and three general teaching suggestions. (DT)

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A History and Overview of Metrication and It's Impact On Education

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I. Introduction

President Nixon's written State of the Union message of January 20, this year, contains the following statement:

"We can enhance our competitive position (in the world's marketplaces) by moving to implement the metric system of measurement, a proposal which the Secretary of Commerce presented in detail to the Congress last year."

On February 29, Senator Daniel Inouye opened 2 days of hearings before the Senate Commerce Committee on pending metric conversion bills with these words:

"We begin today another chapter of hearings on converting the nation to the metric system of weights and measures. The nation that has developed the world's most sophisticated technology is strapped with using a system of weights and measures that was designed to meet the needs of a feudal society.

"A significant portion of our economy has already converted to the metric system. It may well be the case that the issue is no longer whether we shall convert, but whether we should continue our chaotic conversion or embark upon a coordinated, planned program."

And the Senate Committee, in reporting out a metric conversion bill this summer, stated:

"The United States is the last major nation to still cling to the obsolete and confusing customary system of measures that was designed to meet the needs of a feudal society. Consequently, the nation's export

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potential and economic expansion are being handicapped. ...the inherent advantages of the metric system and the flow of world trade will eventually bring about its adoption by gradual evolution in the United States...a carefully planned transition, in which all sectors participate voluntarily... would be far less costly, more efficient, and would minimize economic dislocation."

Thus, it is obvious that the recommendation of the Secretary of Commerce, based on the findings of the U.S. Metric Study, that we change to the metric system through a voluntary, coordinated, national program, has not just been filed away and forgotten.

II. History

How did we get to our present situation? It is interesting to look briefly at the history of both our present, customary system and the metric system; let us begin with a discussion of measuring systems themselves.

The individual has little or no say in the establishment of weights and measures systems, and yet uses them extensively. He is forced by tradition to adopt and learn the systems established by commerce, science, engineering, and law without knowing whether or not it is the one best suited for his use. He hears and uses the terms inch, foot, yard, square inch, square foot, and square yard, but how much does he really comprehend about the system? For example, does he know how many square feet are in a square yard, much less the number of square inches in a square yard or square feet in an acre?

There is nothing natural or unique about a measurement system. It is an invention of man, developed to serve his needs in commerce, industry, and

science. As the system develops and more precise and uniform measurements are needed, measurement standards are developed and defined.

If you would think about the various units used in a measurement system, you would come to the realization that all of them can be reduced to a few base units. The most prominant ones are units of length, mass, time and temperature. From these we can derive a majority of the units that we use (e.g., speed = length/time). In the customary system we have defined the yard, pound, second, and degree Fahrenheit as the four base units.

This customary system, however, is not a rational system as the derived units are not related in a simple manner to the base units. This system is also not a coherent system - one in which there is only one unit for each physical quantity. What has emerged from centuries of use is a hodge-podge of units to fit the needs of various areas and activities of the society. To convert from one unit to another often requires the use of an awkward conversion factor; for instance, both tablespoons and cups indicate volume and 16 tablespoons = 1 cup.

Even though the Imperial system of the United Kingdom, the basis of our customary system, was and is not a coherent system, it was probably the most sophisticated system in use in the world at the time of the American Revolution. It was also a system used uniformly throughout England. So it was natural that we, too, adopted that system for use here in the U.S.

On the European continent there was no such uniformity. Weights and measures differed not only from country to country but even from town to town and from one trade to another. This lack of uniformity led the National Assembly of France on May 8, 1790, to enact a decree, which called

upon the French Academy of Sciences in concert with the Royal Society of London to "deduce an invariable standard for all of the measures and all weights." However, the English did not participate in the French undertaking, so the French proceeded with their endeavor alone. The result is what is known as the metric system, with the meter originally defined as one ten-millionth of the quadrant of the earth.

The metric system was conceived as a measurement system to the base ten; that is, the units of the system, their multiples, and submultiples are related to each other by simple factors of ten. This is a great convenience because it conforms to our common system for numerical notation, which is also a base ten system. So to convert between units, their multiples, and submultiples, it is not necessary to perform a difficult multiplication or division process, but simply to shift the decimal point.

The metric system was not an unqualified success at first--not even at home in France. Use was not enforced, partly because commercial and household weights and measures devices remained scarce. Acceptance came so slowly, in fact, that in 1812, as a practical measure, Napoleon Bonaparte issued a decree partially reinstating the old system while retaining metric measurement standards. Only after a delay of 25 years was the metric system officially restored in France by passage of a law in 1837 making its use compulsory throughout the country after January 1, 1840.

After that, the metric system began to spread internationally at a rapid pace. By 1850 the Netherlands, Greece, Spain, and parts of Italy adopted it. By 1880 seventeen other nations--including Germany, Austria-Hungary, Norway, and most of South America--had changed to metric. And by 1900 eighteen more were added to the list.

The development of the metric system and its increasing usage was not going unnoticed in the U.S., and several attempts were made to get the U.S. to adopt the metric system, the first by Thomas Jefferson. However, the only action of substance to occur in that time was an Act of Congress, passed in 1866, making the use of the metric system legal in the U.S. (and it is the only such "legal" system even today).

A result of this pro-metric activity was the development of organized opposition. While many individuals and groups objected to changes in the measurement system, the first to adopt opposition to the metric system as its main objective was the International Institute for Preserving and Perfecting Weights and Measures. It was founded in 1879 and it was clear that the weights and measures to be preserved and perfected were strictly Anglo-Saxon.

Regardless of the existence of groups such as this, pro-metric individuals pushed onward, and an attempt to convert the nation in 1896, almost succeeded. A bill was introduced in the Congress providing that all Government departments should "employ and use only the weights and measures of the metric system" in transacting official business and that in 1899 metric would become "the only legal system...recognized in the United States." It passed the House by the bare margin of 119 to 117. But immediately, opponents forced a reconsideration and launched an attack stressing the difficulty of making a change. The bill was sent back to Committee, and there it died.

Over the next ten years, more than a dozen bills dealing with the metric system were proposed and many were debated. Support for the metric system continued from scientists, educators, and some government officials.

The opposition at this time was better organized and more effectively led than ever before. They rallied the support of engineers, manufacturers, and workmen and claimed to be "practical men, not philosophers or theorists." They charged that the metric system had been a practical failure in countries which had adopted it--i.e., that English and U.S. weights and measures were still the ones most commonly used even in those countries, and that most of the world's commerce was being carried on in terms of English and U.S. units.

As we know, these efforts were successful and no metric conversion legislation was passed by the Congress. Eventually, interest in metric died down and in the period from the 1920's until the early 1960's, only two Congressional hearings were held although metric proponents in Congress did introduce some 30 metric bills.

The resurgence of science following the launching of the Sputnik caused renewed interest in the metric system. The idea of going metric or at least authorizing a metric study gained momemtum in Congress. Hearings were held, although in the House none of the proposals ever reached the floor. A sense of urgency was still lacking.

Finally, in 1965, the President of the British Board of Trade announced in Parliament the United Kingdom's intention to adopt the metric system over the course of the next ten years. Britain's action made it clear that the U.S. would soon be one of the very few nations that still adhered to the customary system. After a series of efforts by several Congressmen, an acceptable bill calling for a metric study was drafted. It became Public Law 90-472, which was signed into law in 1968.

III. What the Study did

Public Law 90-472 says, in one sentence, "What action, if any, should the U.S. take with respect to increasing worldwide (and domestic) use of the metric system?"

To find the answer, we sought inputs from all sectors of the society. The actual investigation and analysis were carried out through a series of public hearings, called National Metric Study Conferences, and a number of in-depth, supplementary investigations. These treated such topics as: 1) a detailed survey of the present situation and views of manufacturing industries, 2) a similar look at the situations of non-manufacturing businesses, 3) a study of metric implications on the education sector, 4) a survey of metric impacts in international trade, 5) a special study of measurement-related international standards problems, and 6) a survey of the attitudes of U.S. consumers toward the metric system.

IV. Study Findings

I hope you will agree it was a very comprehensive study. It certainly was very complex, but its findings were fairly straight-forward. They were: (1) The U.S. already makes some use of the metric system and metric use in the United States is increasing. Examples are easy to find. Metric is the only system used in the olympics. Our astronauts use it on the moon. The pharmaceutical, ball bearing, and photographic industries all use metric. We have all heard of 35 mm film; and what about 100 mm cigarettes? In addition, many of our canned foods have supplementary metric units on their labels. These trends are so pronounced that it is apparent that we will eventually become a metric country - even without any further Government action.

(2) A great majority of businessmen, educators and other informed participants in the Study believe that increased metric use is in the best interest of the U.S. and an even larger majority believe it is better for the nation to increase its metric use by plan rather than by no plan.

(3) A final finding concerns the costs and benefits of metrication. Such costs and benefits are extremely difficult, if not impossible, to evaluate in dollars and cents. This conclusion is verified by the British experience that such estimates cannot be made even after a product has been converted to the metric system because the metrication costs are hard to identify. It must be remembered, however, that in any attempt to make such an evaluation the meaningful comparison is between increased metric use by plan and with no plan, rather than between increased use and no such increase because the latter course is not available; metric use will undoubtedly continue to increase regardless of what action the Congress takes with respect to metrication. The meaningful comparison leads to the conclusion that the costs and benefits of increasing metric use by plan would be more favorable than those incurred through continued drift into mixed customary and metric usage.

V. Secretary's Recommendations

These inputs led to recommendations by Secretary of Commerce

--that the U.S. change to the International Metric System (SI) deliberately and carefully;

-- that this be done through a coordinated national program;

--that Congress assign the responsibility for guiding the change, to a central coordinating body responsive to all sectors of our society;

--that within this guiding framework detailed plans and timetables be worked out by the sectors themselves;

--that early priority be given to educating every American schoolchild and the public at large to think in metric terms;

--that immediate steps be taken by Congress to foster U.S. participation in international standards activities;

--that in order to encourage efficiency and minimize the overall costs to society, the general rule should be that any changeover costs shall "lie where they fall";

These can be paraphrased as follows:

1) In 10 years we would switch the roles of metric and customary units:
   . the U.S. would become predominantly metric, but not exclusively so
   . some sectors of the economy would take less time, others more; but all could be accommodated
2) Rule of reason would guide the change:
   . most things would be changed only when worn out or obsolete
   . some change early, some slowly, some never for metric reasons alone
3) A central coordinating body should be established to:
   .help all sectors work out plans and timetables and
   . ensure all these plans are meshed
   . work out a program of public education
   . anticipate and deal with special problems

So, the Congress has the report of the U.S. Metric Study and the Secretary's recommendation. The next step is up to them. Legislation has been introduced in both the Senate and the House. The Senate has acted, but what about the

House? I wish I knew the answer but of course I do not. Still, most informed persons feel it is only a matter of time, so let us look at what happens "if."

VI. What Metrication Is and What It Is Not

It appears, if the Congress passes an appropriate conversion act, that the country will increase its metric use in a reasoned way, making changes when they can conveniently be made and not making them when they serve no useful purpose. In the manufacturing industry, as products proceed through their evolutionary process of design and redesign, the components and products that come up for redesign would be designed by using metric measurements rather than our customary measurements. On the other hand, components and products that are not due for redesign would continue to be produced without change; it would not be reasonable or necessary to redesign such items for the sole purpose of making them metric.

For example, the automobile industry says that over any 12-year period all of the components in an automobile will have been redesigned. The most sensible and most economical way to change the design of the entire automobile to metric would be to redesign each component to metric standards when it is scheduled for redesign--preferably to international metric standards, if these are advantageous to the United States. Of course, the automobile industry would want to work closely with the Metric Coordinating Board in coordinating its changes with the changes of its suppliers.

A milk packaging machine, however, that perfectly well meets its needs and is not scheduled for redesign in the foreseeable future would continue to be produced as it has been in the past. When the country's metrication

schedule calls for packaging milk in liter rather than quart containers, for example, the milk machine would be modified only to the extent necessary to have it fill liter containers rather than quart containers, which are 5% smaller.

In the case of most widely used items and practices, no change would be made under a metrication program. Our railroad tracks are a prime example--their gauge will remain unchanged since their purpose is to fit the wheels of the rolling stock. So will the length of our football fields remain 100 yards just as the lengths of horse races are today measured in furlongs. In the Middle West, and perhaps elsewhere, the land was surveyed in one-mile segments, leading to the practice of designating roads as "One Mile Road," "Two Mile Road," etc; there would be no occasion to change the names of these roads any more than to drop from the language expressions like, "Give him an inch and he'll take a mile."

What about all of us as just plain citizens? The primary issues of metrication concerning most individuals is related to change and the concern of having to adjust to something new. This period of learning will cause problems and a little confusion. But once we learn metric, things will be easier.

People often express feelings of, "I'm too old to learn," or, "I will never be able to adjust," And it is true we would all be learning something new. Should there be a program of metrication, these feelings of fear, anxiety and apprehension that many people possess must be contended with if the program is to be conducted smoothly.

Accompanying metrication would have to be an extensive and intensive program of educating the public on the nature and merits of the metric system, the areas where change would take place, the reasons for change, and the proposed outcome, including advantages. The media available for education are numerous: product advertising, public service advertising, television and classroom courses, pamphlets, and information given at the time of purchase or use, to name a few. The specific media and content, of course, will depend on the audience, their specific needs and attitudes.

VII. Education Impact

What are the metric implications for education? It is generally acknowledged - and recognized in one of the Secretary's recommendations - that the present situation (rapidly increasing metric usage plus the likelihood of Congressional action in the future) is such that attention must be paid now to the question of improving both the quantity and the quality of metric education. Admittedly, as long as we do not officially "go metric", we cannot consider phasing out customary measurement learning, but even until we do go metric officially, we need to be teaching metric more thoroughly in our schools.

Another reason for early movement in metric education - aside from the present use of metric - is that we need to be sure that every child now in school is adequatly equipped for the future. There is really no question but that those students starting school this year will be graduating into a metric world. If they do not adequately learn metric, they certainly will be ill equipped for the world they will inherit.

There is one more reason for prompt action - one that maybe the students will enjoy. Their parents are eventually going to need to learn metric - so they can shop in metric stores, cook with metric recipes. Our children - if they have already learned metric in the classroom - will undoubtedly prove invaluable in helping their parents learn metric.

VIII. Advantages - Disadvantages of Metrication

Educators in general have long been in favor of metrication. For example, the National Education Association is on record as saying (a 1970 resolution):

> The NEA believes that a carefully planned effort to convert to the metric system is essential to the future of American industrial and technological development and to the evolution of effective world communication. It supports federal legislation that would facilitate such a conversion.

Why is it that education - or at least the key education associations - are so inclined? The answer is evident when you look at the advantages and disadvantages of metric education - as compared to customary measurement education.

The chief educational advantage of using the metric system lies in the simplification of teaching and learning how to measure. This advantage arises from the simple interrelations of units mainly based on multiplication by 10 and from the ease of computing with decimal fractions and whole numbers.

An obvious educational advantage would be that the educational system would no longer be burdened with teaching two systems of measurement as is now necessary. At the same time, much of the customary drill in fractions

could be reduced, although we would of course need to retain an easy familiarity with halves, thirds, quarters, and fifths (and perhaps sixths and eights).

What is the major advantage of the customary system? That it is familiar to most people - and of course that the metric system is not.

With these facts in mind, it is easy to see why metric is favored by educators in general. But there is even another advantage of going metric, perhaps one that outweighs all the others.

I am speaking about the opportunity during the changeover of making what some educators feel are certain much needed curriculum changes - what Dr. Berol Robinson, of the Education Development Center and author of the Metric Study's Education report, calls "another round of mathematics curriculum reform."

He is referring to such things as:

- early introduction of decimal fractions, with corresponding reinforcement of the place value system
- a considerable downplay of unessential skills in manipulation of fractions
- an upgrading of effort in teaching measurement in the schools

Whether or not such reform is needed I leave to you and other educators to decide. The important point is that metrication will provide an ideal time for such changes should they be desired.

IX. Areas of Metric Impact

So, it seems to be generally agreed that metrication is coming and that it may indeed be good for education. The question then arises

"Where will the change impact education and how can this impact best be handled?"

I will consider three broad areas: curricula and associated text books; teacher training; and other educational materials, including library books and lab and shop equipment. Of course, I cannot speak as an expert in any of these areas. But let me give you a few comments as to how a metric expert views these impacts. Perhaps they will help you assess these impacts for yourselves.

Curricula/textbooks

The important area of curricula change is probably quite complex, especially in light of any of the above proposed changes that might take place. It seems apparent that what we are talking about is not merely a mechanical conversion from customary to metric units in existing curricula, but substantive changes of some kind. I only hope that, once a national metric program is enacted, national organizations will support such new curriculum developments.

Once they are ready, then, of course, we need revised texts. The process of getting revised books into the schools should not prove to be a big problem.

Dr. Robinson, in the Education report, states, based on discussions with textbook editors "In the course of normal reprinting and revision practice, many textbooks could undergo metric conversion in a period of 5 years or less. If a lead time of 2 or 3 years were provided for changes, and if the people who select and buy textbooks were advised that changes were in process, and if they adjusted their replacement and renewal schedules accordingly, then new materials would reach students promptly after the beginning of a metric conversion period."

The cost? If this method is followed, it would easily be absorbed in the usual replacement cost.

Teacher Training

Certainly, some training will be necessary for education to enable them to properly teach metric.

Most educators, Dr. Robinson reports, agree that 8 to 15 hours of inservice training would suffice to prepare teachers for going metric. Most schools have inservice training programs that could easily accommodate the needed training.

However, there will be a problem for the small percentage of teachers with no such inservice training available. Special efforts will have to be made to ensure that these teachers are reached, especially those who are geographically isolated. There is another possible side benefit here, by the way. Perhaps the need for training for metric conversion may prompt the formation of a regular program. How should the training be done? Dr. Robinson recommends that it should be tightly structured, well organized, and preferably condensed into a short time span, ideally just before new metric materials are used.

Other Educational Materials

First, concerning printed and other "software" - films, maps, etc. - Dr. Robinson reports "replacement of library books and encyclopedias would not be an obstacle, in light of usual replacement cycles and given a 5 to 10 year conversion period. He also reports that much of the other materials turn over with a typical lifetime of less than a decade and as such pose no special problems.

But what about "hardware" - the lab and shop equipment, including things in office and home economics training. Without a census of all schools, it is impossible to know the magnitude of change needed. But we can say it is considerable and could be costly - although such costs would likely be small compared to total education budgets. Dr. Robinson reports that the necessary modifications to existing equipment could likely correspond to a year's depreciation; and that this cost would not have to be taken all at once but could be spread over several years.

Differences in cost may arise due to the way the change is viewed. It is interesting to compare two responses reported by Dr. Robinson to a question concerning the changes:

(1) One technical school reported: "It is not worthwhile to modify an old machine if modification should cost as much as 10% of the price of a new one; we would have to buy new machinery." and

(2) One Vocational School said: "We would modify our own machines - it would give the students some meaningful projects to work on."

So, metric conversion will have a great deal of impact, but generally speaking, a well-planned program, given proper time to make the changes, need not be overly expensive or overly hard to do. The key is the proper planning and proper timing.

X. Implementation of Changes

The key to the success of any metric program is, of course, its acceptance in the schools throughout the country. We have a situation, as you are probably aware, where each of our 20,000 plus school systems are the ones that decide what is taught, so it is important that careful thought be given to devising a program that will gain such acceptance.

I am not sure exactly what such a program should include - or even what will work; I am not sure anyone does. I would like to outline briefly some ideas we have.

It seems that such a campaign to promote metric education might include some or all of the following:

- urge authors, editors, and publishers to make suitable metric materials available as soon as possible
- advise school boards of the need for metric education and the need to consider their textbook purchases in the light of probable changes
- issue guidelines to authors and editors concerning correct metric usage
- endorse authoritative recommendations for curriculum change
- promote the publication in the periodicals teachers read of articles on the proper use of metric, on what changes in going metric and what does not
- encourage papers and discussion on metrication at conventions and other meetings of associations and other teachers' organizations
- develop teacher training programs
- develop equipment modification schemes

The obvious question is what organization or group of organizations should do this.

We at NBS are starting on some but we do not have the expertise to do much more. The U.S. Office of Education, National Education Association, National Council of Teachers of Mathematics, American Vocational Association, and others have an interest. Maybe what is needed is a unique coalition of all interested parties.

XI. How to Teach Metric

I have said about all I can related to changes needed in education and how they will impact these operations. I would like to switch gears briefly and give you a few ideas about how - and how not to - teach metric. Please remember - these are from a non-educator who knows a little about the metric system. I think, though, you probably will agree with their validity.

- It is best if both students and teachers learn to use metric units by measuring familiar things in metric units only. I would warn against a general attempt to teach metric equivalents and conversion factors from customary to metric and vice versa.
- Let me emphasize the idea of learning by doing. It is of course possible to learn metric units by study only. But the familiarity with metric units that is needed can only come by actually measuring things plus using the new measurement language in meaningful, everyday expressions.
- Finally, it would seem wise to avoid - in most cases - supplementary metric workbooks or pamphlets along with existing texts. The books and curricula should be revised to achieve all of the possible benefits.

IX. Conclusion

I hope I have given you a reasonable idea of what things will be like if and when we "go metric." Metric is coming, and early attention to education is vital. I hope you have not been overwhelmed by any prospective changes I have outlined. Rather, I hope I have given you enough general infromation to start you thinking about what metrication really means to your area of concern.